

Simulations of Large Scale Structure observables in LSST

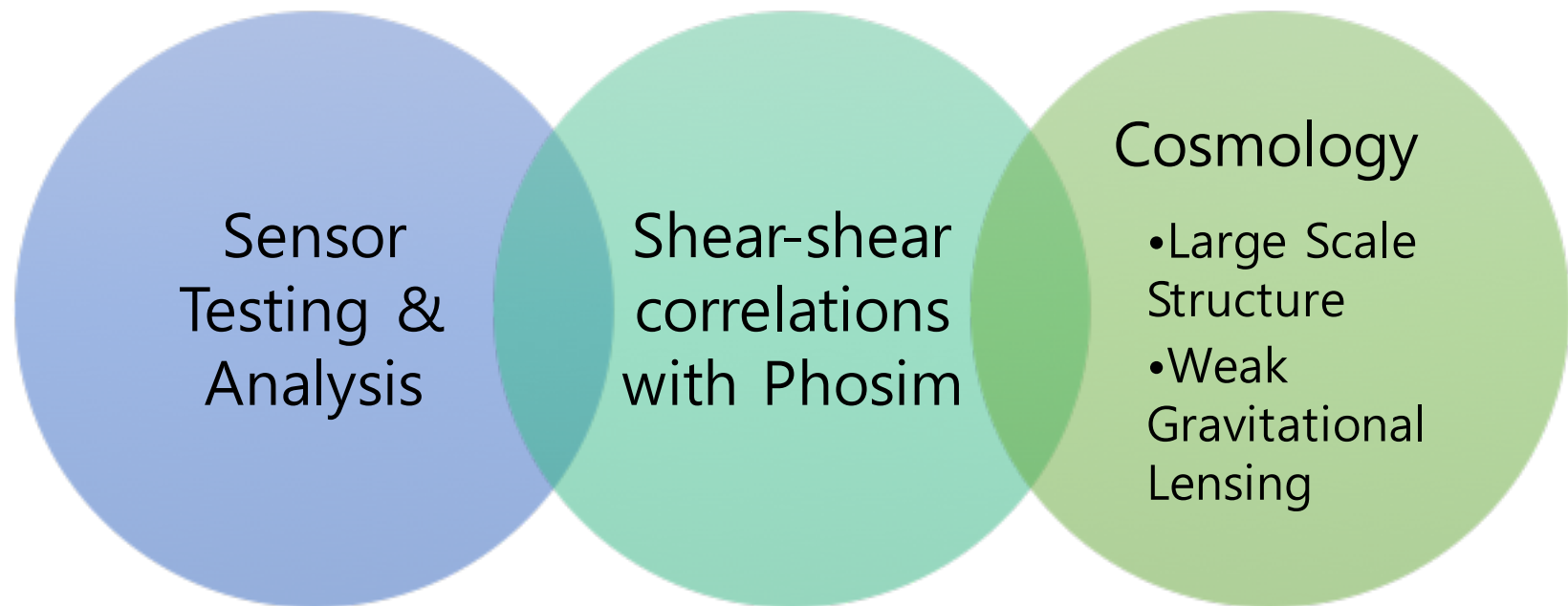
HyeYun Park

Stony Brook University & Brookhaven National Laboratory

Thesis Proposal 11/04/2016 2PM

Group meeting 11/01/2016 11:30AM

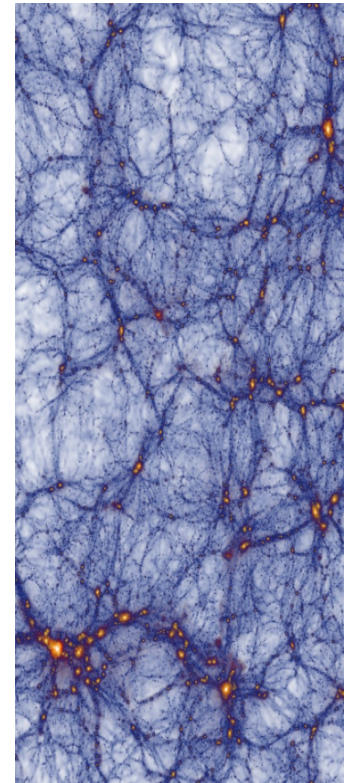
Overview



Motivation

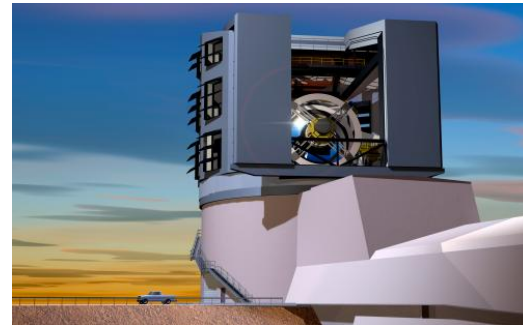
- Large Scale Structure WG and Weak Lensing WG are science Working Groups inside LSST DESC collaboration

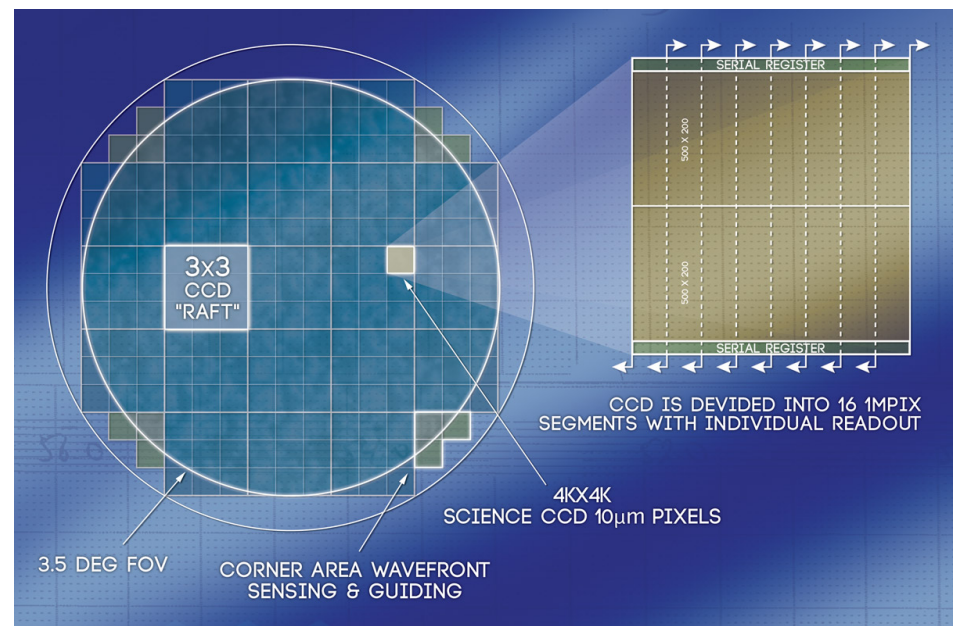
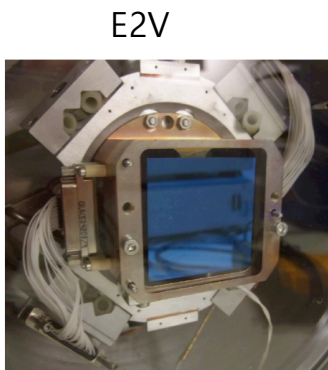
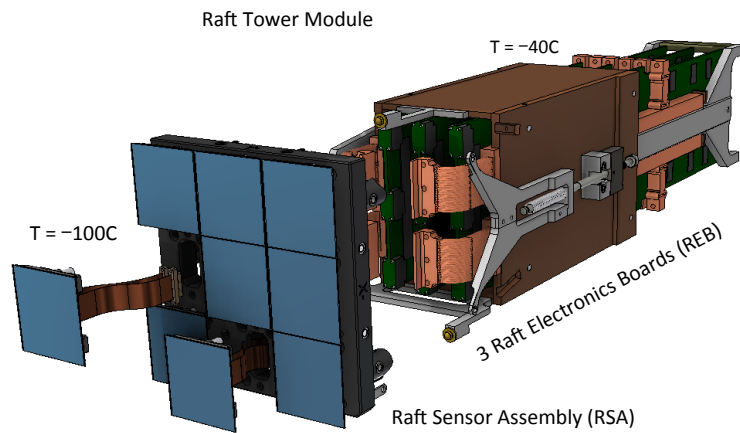
LSS	<->	WL
<ul style="list-style-type: none">• Galaxy-galaxy correlation• BAO• Shape of power Spectrum	<ul style="list-style-type: none">• Galaxy-shear correlation	<ul style="list-style-type: none">• Shear-shear correlation



Motivation

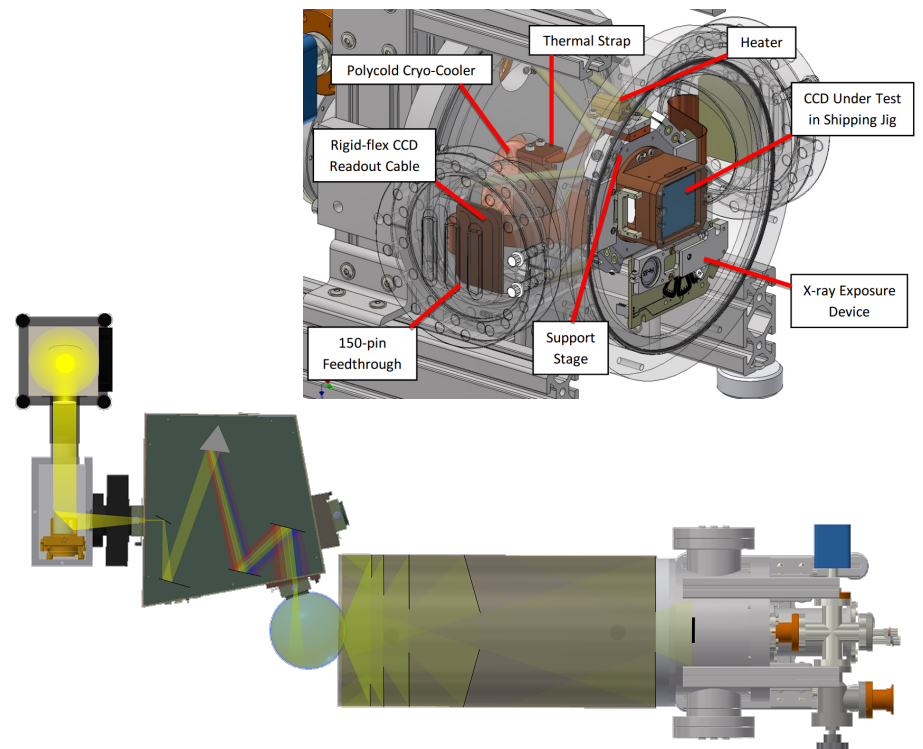
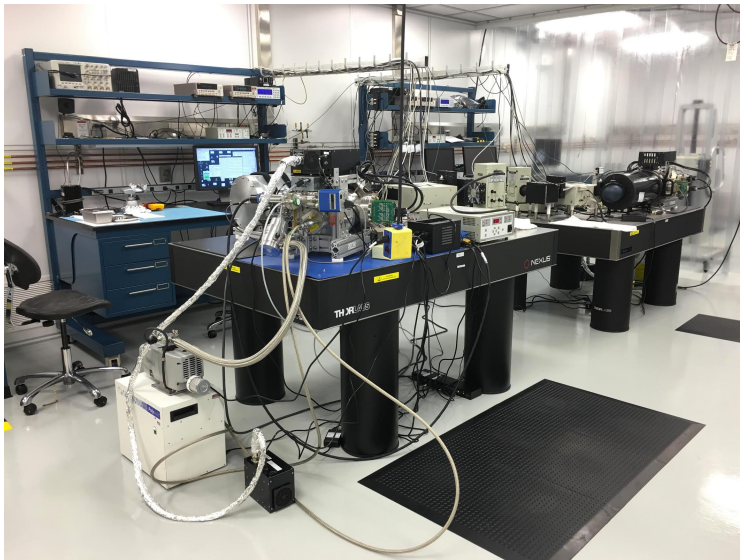
- **LSST**(Large Synoptic Survey Telescope) in Chile is 10 year survey project designed to address four areas :
 - Dark Matter and Dark Energy
 - Solar System
 - The Transient Optical Sky
 - Milky Way
- LSST survey will yield a sample of ten billion galaxies over a huge volume





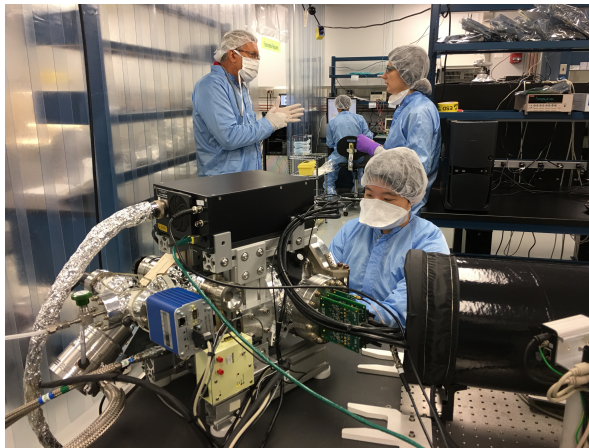
Teststand 3 in the cleanroom

- Electro-optical testing of CCDs



Picture credit : R.Coles

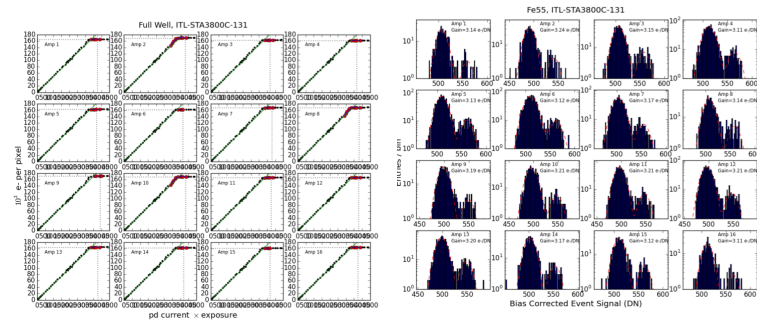
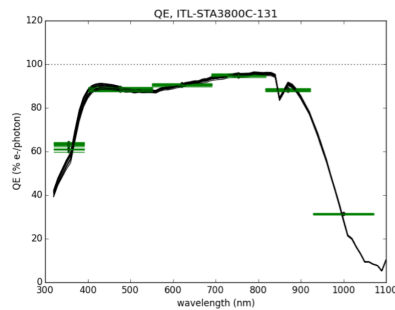
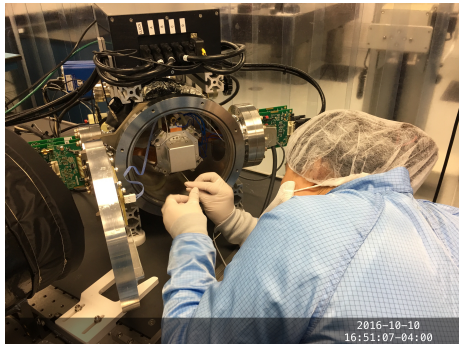
Sensor Testing & Analysis



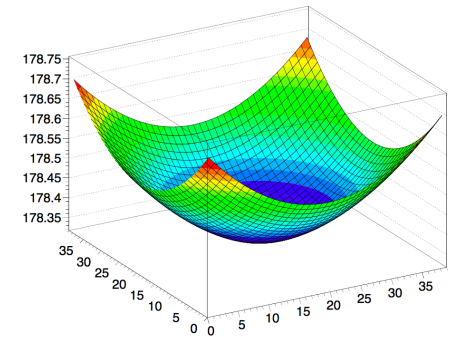
1 Summary

Status	Spec. ID	Description	Specification	Measurement
✗	CCD-007	Read Noise	$< 8 e^- \text{ rms}$	$7.79 - 8.78 e^- \text{ rms}$
✓	CCD-008	Blooming Full Well	$< 175000 e^-$	$161498 - 170522 e^-$
✗	CCD-009	Nonlinearity	$< 2\%$	max. fractional deviation from linearity: 3.5×10^{-2}
✓	CCD-010	Serial CTE	$> 1 - 5 \times 10^{-6}$	$1 - 2.53 \times 10^{-6} \pm 1.20 \times 10^{-6}$ (min. value)
✗	CCD-011	Parallel CTE	$> 1 - 3 \times 10^{-6}$	$1 - 5.44 \times 10^{-4} \pm 3.53 \times 10^{-6}$ (min. value)
✗	CCD-012	Active Imaging Area and Cosmetic Quality	$< 0.5\%$ defective pixels	defective pixels: 306336 (1.8993%)
...	CCD-012a	Bright Pixels	...	1640
...	CCD-012b	Dark Pixels	...	3753
...	CCD-012c	Bright Columns	...	151
...	CCD-012d	Dark Columns	...	0
...	CCD-012e	Traps	...	0
...	CCD-013	Crosstalk	$< 0.19\%$...
✓	CCD-014	Dark Current 95th Percentile	$< 0.2 e^- s^{-1}$	$1.80 \times 10^{-1} e^- s^{-1}$
✓	CCD-021	u Band QE	$> 41\%$	62.4%
✓	CCD-022	g Band QE	$> 78\%$	88.6%
✓	CCD-023	r Band QE	$> 83\%$	90.6%
✓	CCD-024	i Band QE	$> 82\%$	94.9%
✓	CCD-025	z Band QE	$> 75\%$	88.3%
✓	CCD-026	y Band QE	$> 21\%$	31.3%
✓	CCD-027	PRNU	$< 5\%$	max. variation = 4.06% at 350 nm
✓	CCD-028	Point Spread Function	$\sigma < 5 \mu$	4.84μ

Picture credit : R.Coles

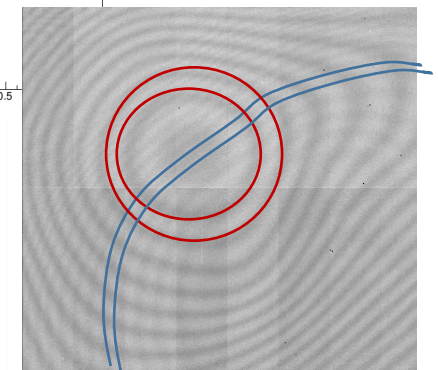
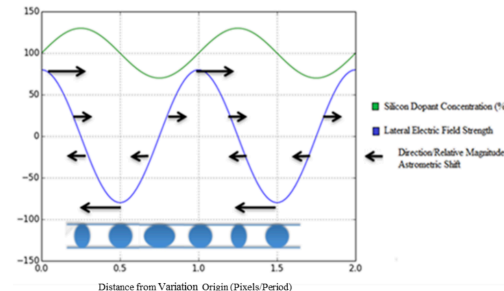
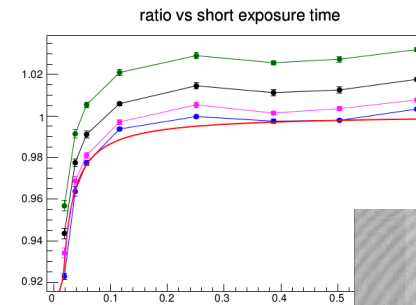


Sensor Testing & Analysis

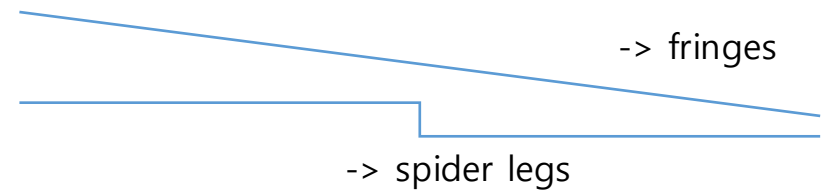
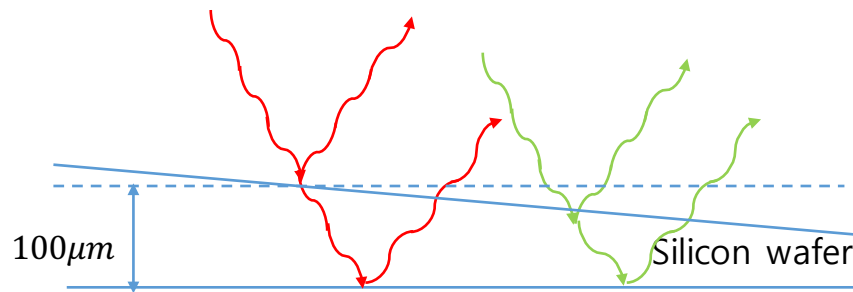


- Important to study sensor effects as they may bias science observables

- Shear-shear correlation using PHOSIM
- Non-uniformity
- Non-linearity with Shutter artifacts
- Fringes and Spider legs
- Tree rings
- Charge Transfer Efficiency(CTE)



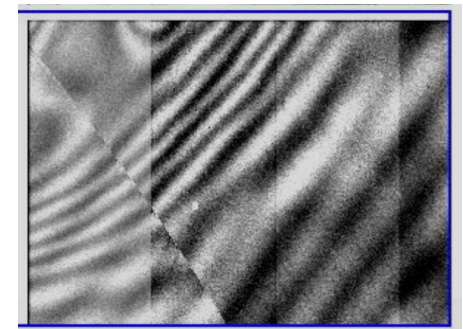
Fringes



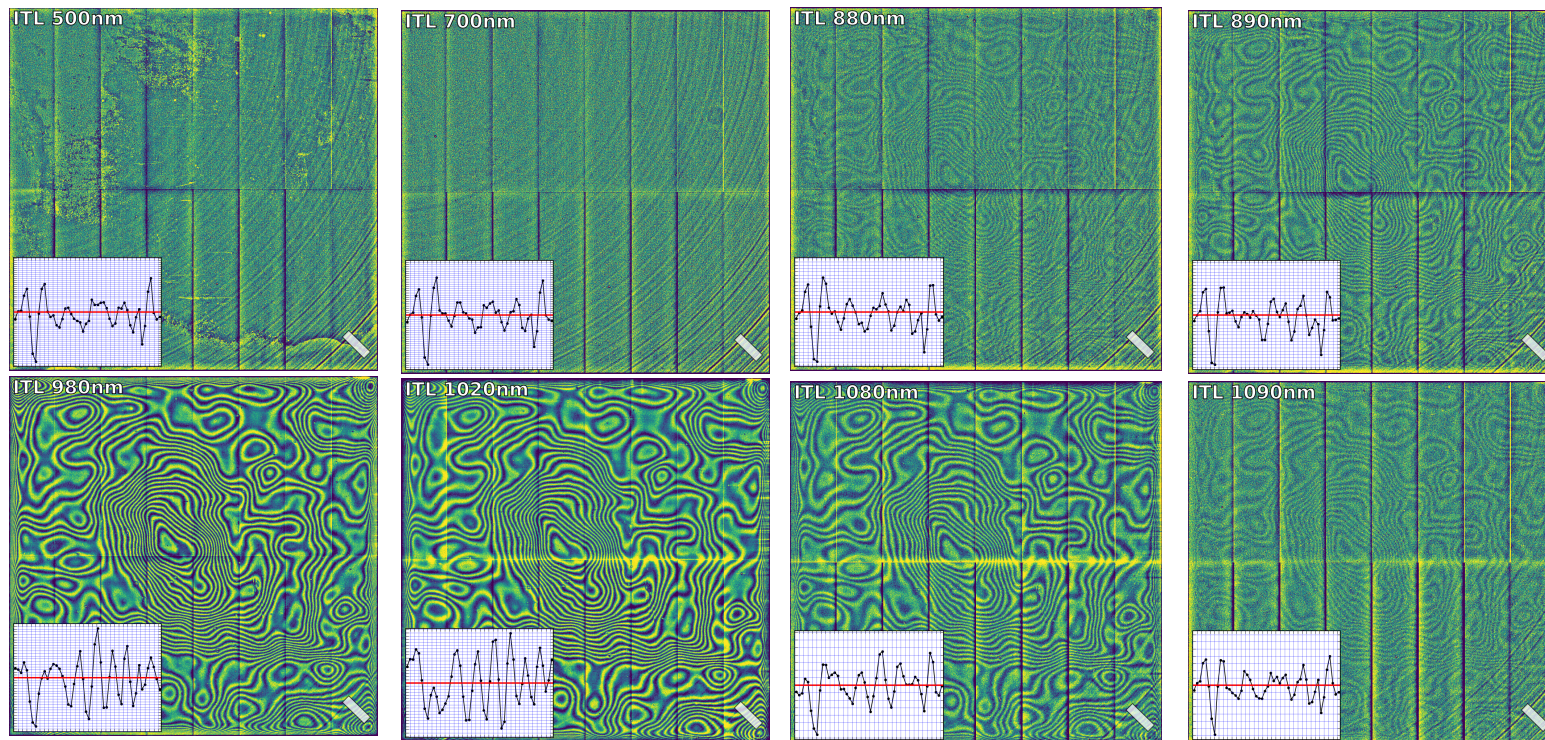
$$d = \frac{\lambda}{2} \cdot \frac{1}{3.5} \cdot n$$

Refractive index of silicon
 $n = \text{odd for dark}$
 $= \text{even for bright}$

- Silicon wafer doesn't have uniform thickness
-> fringes
- During manufacture process, silicon wafer is ground and it brings thickness differences -
> spider legs



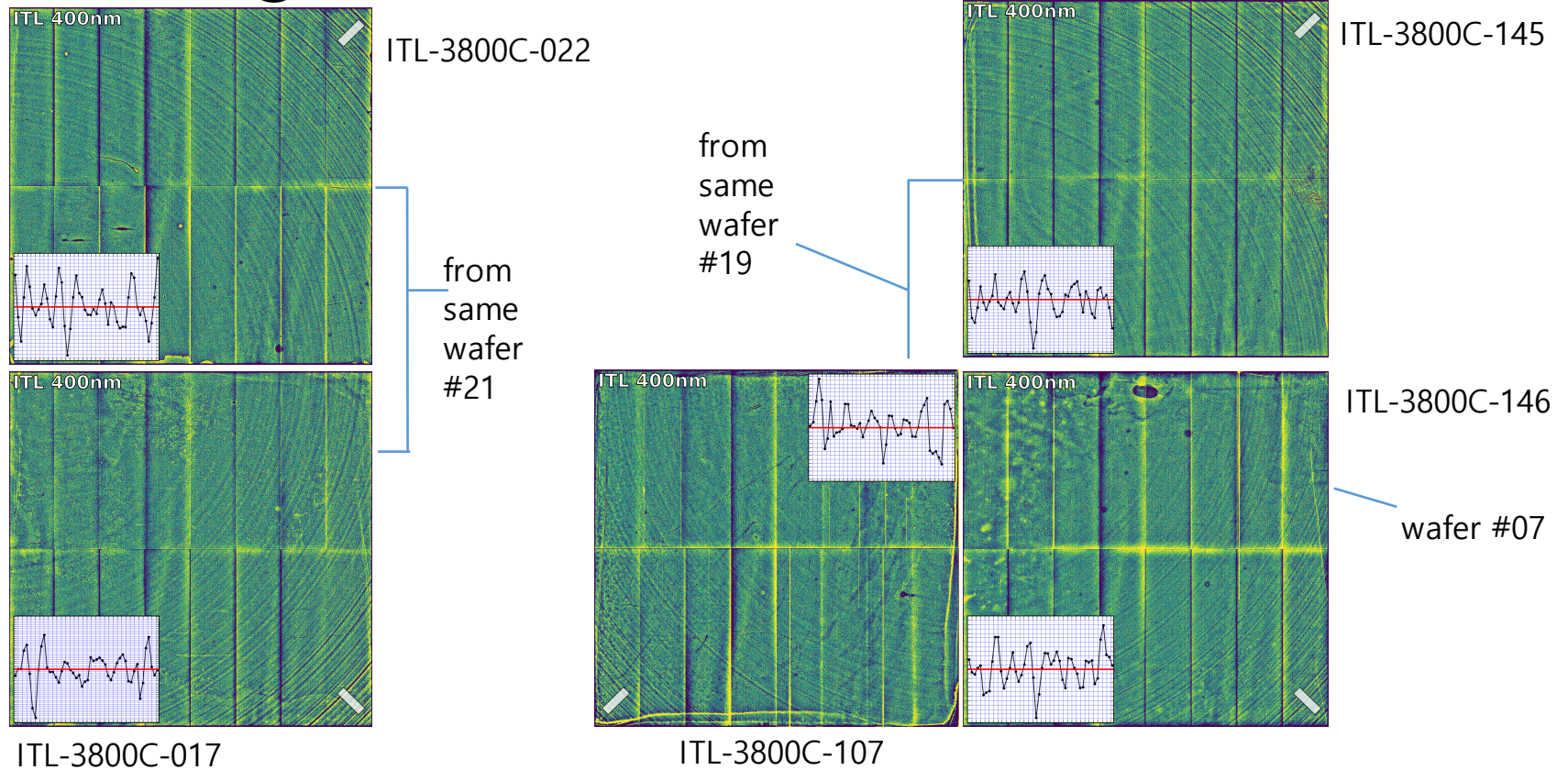
Fringes & Tree rings



ITL-3800C-017 flat images

*Used David Kirkby's code to produce images emphasizing the effect

Tree rings in different sensors



Charge Transfer Efficiency

- Some of the electrons remain behind when transferring from one column(row) to next column(row).
- CTE is a measure of ability of the device to transfer charge

$$CTE = 1 - CTI$$

Due to
remaining charges

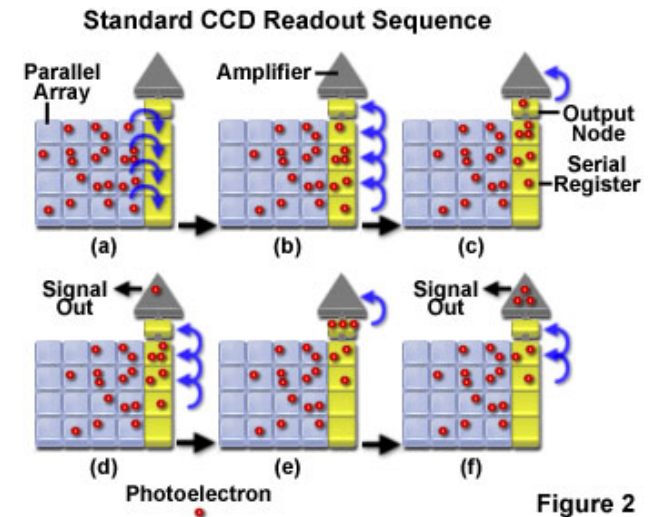
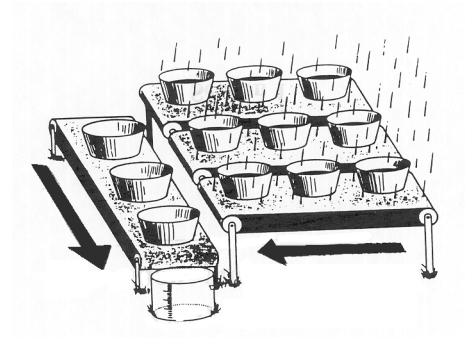


Figure 2

PHOSIM : Photon Simulator (J.Peterson et al)



object (source)

wavelength, RA, DEC, x&y location, number, type,.. etc

atmosphere

clouds, wind, temperature, water pressure,... etc

telescope

dome seeing

tracking, shutter error,... etc

instrument

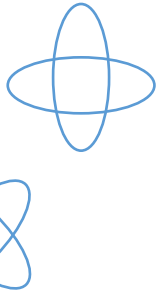
ccd temperature, silicon thickness,...etc

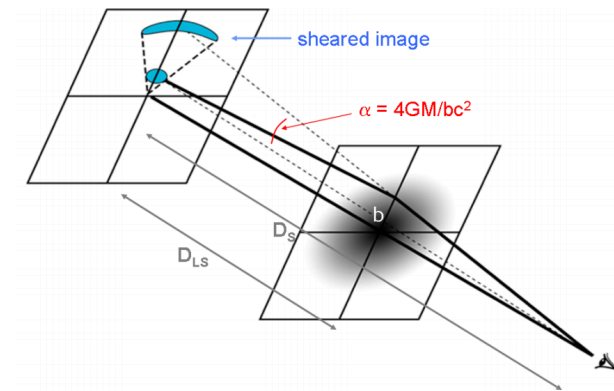
Shear-shear correlations

- Shear : used MCMC mode in ngmix (E.Sheldon) to fit 2D Gauss (x, y, flux, sigma, g1, g2)

$$\vec{g} = g_1 + ig_2$$

$$g_1 = \frac{I_{11} - I_{22}}{I_{11} + I_{22}} = \frac{a - b}{a + b}$$

$$g_2 = \frac{2I_{12}}{I_{11} + I_{22}}$$




*LSST Science Book, Version 2.0 (p501)

Shear-shear correlations

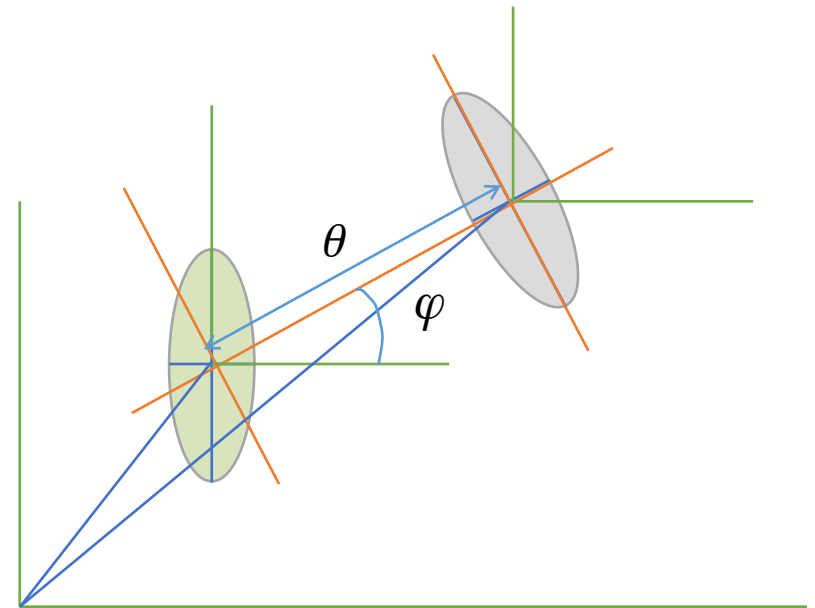
- Correlation function : used TreeCorr (M.Jarvis) and notations from arxiv:1206.137804 (Chihway Chang)

$$\xi_+(\theta) = \langle X_+(\theta_0)X_+(\theta_0 + \theta) \rangle + \langle X_x(\theta_0)X_x(\theta_0 + \theta) \rangle$$

$$\xi_-(\theta) = \langle X_+(\theta_0)X_+(\theta_0 + \theta) \rangle - \langle X_x(\theta_0)X_x(\theta_0 + \theta) \rangle$$

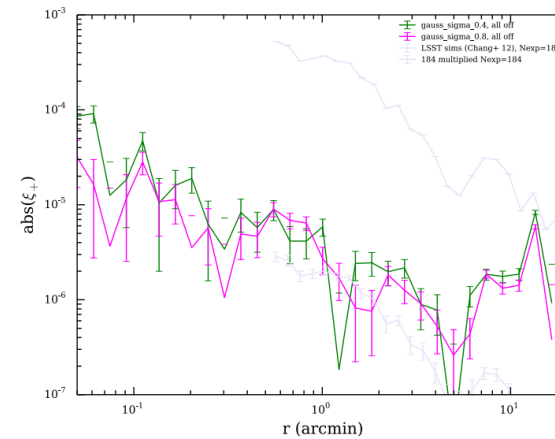
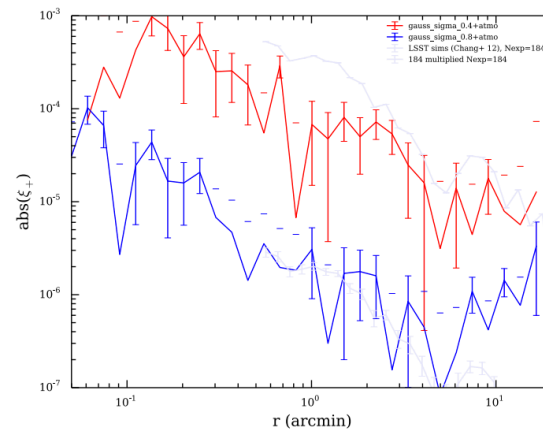
$$X_+ = \text{Re}(\vec{g}e^{-2i\varphi})$$

$$X_x = \text{Im}(\vec{g}e^{-2i\varphi})$$



Shear-shear correlations

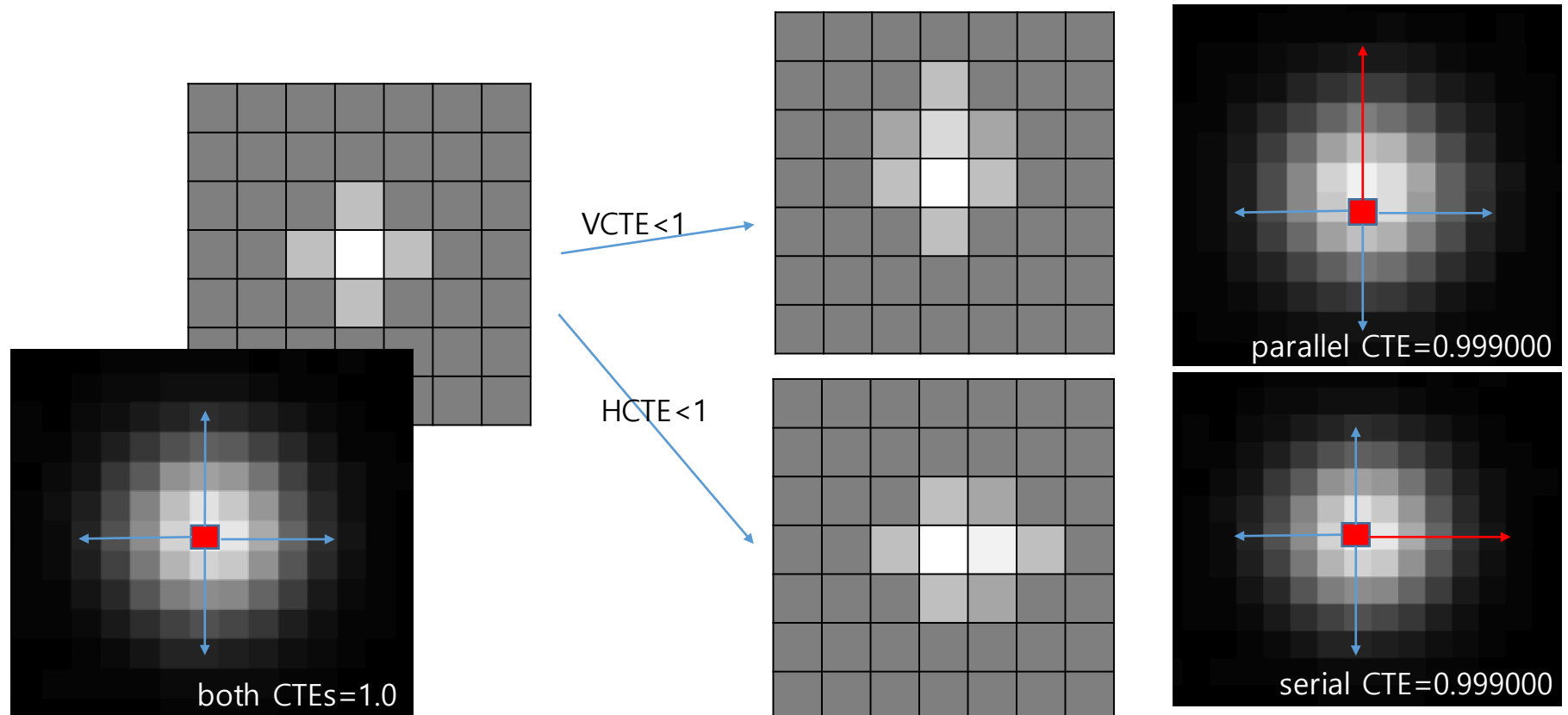
- With atmospheric effects on, larger object brings less correlation
- Without atmosphere, size doesn't affect much on correlation



Shear-shear correlations with CTE study

- Using PHOSIM, 10,000 gaussian objects($\sigma=0.4$) randomly spread over one raft(R22) was simulated.
- Cleared every other effects but left the sensor effect and changed CTE values :
 - 1.000000
 - 0.999995 (specification of LSST for ITL sensors)
 - 0.999000

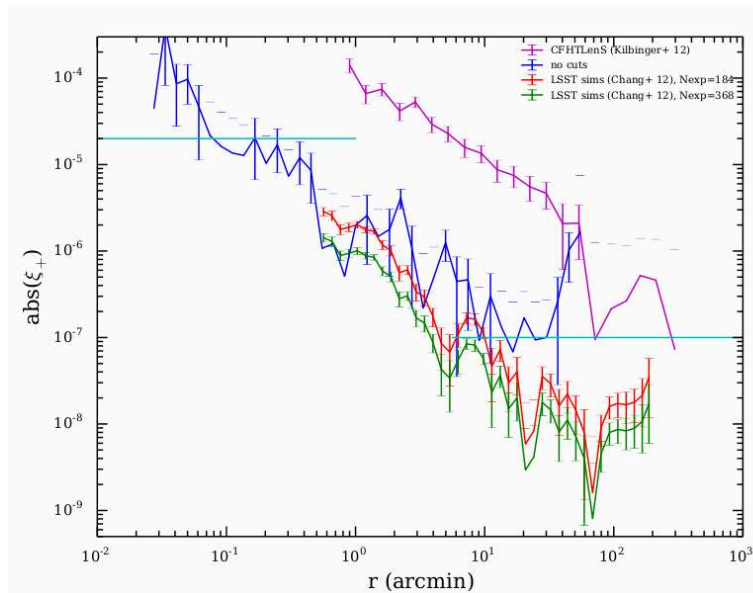
Shear-shear correlations with CTE study



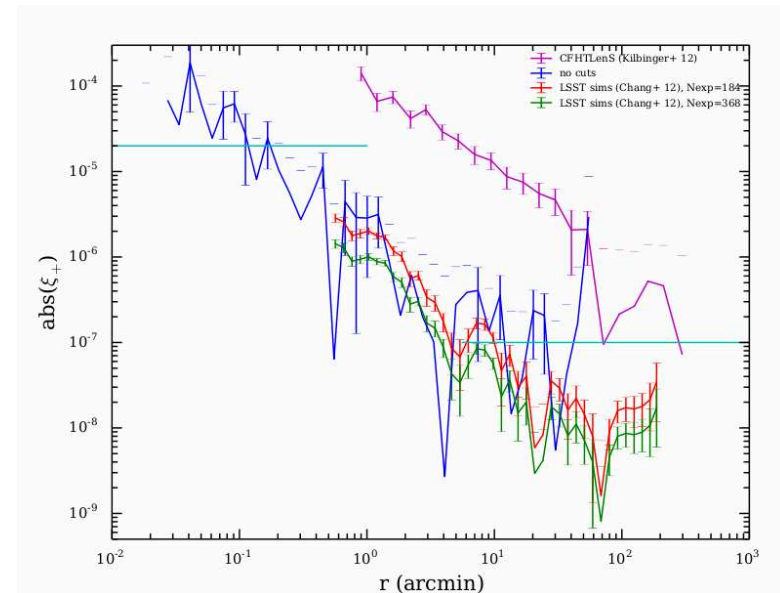
Shear-shear correlations with CTE study

-Compare shear correlation

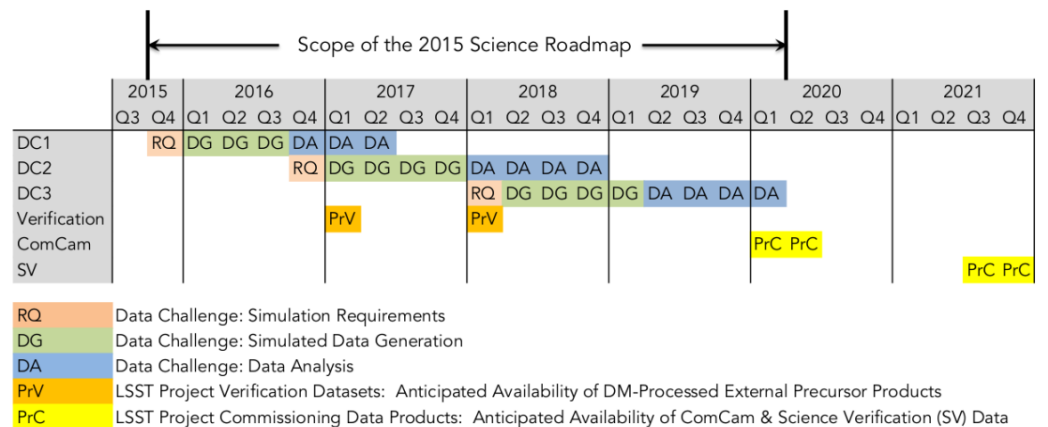
Parallel CTE=0.999000



Both CTE=1.000000



- Apply Phosim simulations to LSS
- Analyse Data Challenges for DESC(Dark Energy Science Collaboration)
 - DC1 in progress
 - DC2/3 planned for 17/18



Large Scale Structure WG

-LSST DESC Data Challenges

- Goals:
 - Work on all systematic effect in PHOSIM
 - Study instrument performance
 - Learn Galaxy-galaxy correlation / Galaxy-shear correlation
- Additional goals:
 - Run codes to compare data and theory
 - Run codes on existing datasets, such as SDSS and DES